1) \( \text{Eh, } f_{O_2}, \text{ and } p_e \). Consider a solution in which \( \text{Eh} = +100 \text{ mV} \) and \( \text{pH} = 6.5 \).
   a. Calculate \( p_e \) for this solution.
   b. Calculate \( f_{O_2} \) for this solution.

2) Consider the following redox half cell reactions:
   \[ \text{SeO}_4^{2-} + 3\text{H}^+ + 2e^- = \text{HSeO}_3^- + \text{H}_2\text{O} \] ...and...
   \[ \text{HAsO}_4^{2-} + 4\text{H}^+ + 2e^- = \text{H}_3\text{AsO}_3^0 + \text{H}_2\text{O} \]
   a. Using the \( G^0 \) data in Appendix B of Faure, calculate the \( E^0 \) values for the half cell reactions. (Hint: What is the \( G^0 \) of an \( e^- \)?)
   b. Calculate the \( \text{Eh} \) in a system with \( \text{pH} = 6.5 \) and equal activities of the reduced and oxidized species in the redox couple.
   c. Calculate the \( \text{Eh} \) in a system with \( \text{pH} = 6.5 \) and \([\text{SeO}_4^{2-}] / [\text{HSeO}_3^-] = 0.1\)
   d. Calculate the \( \text{Eh} \) in a system with \( \text{pH} = 6.5 \) and \([\text{HAsO}_4^{2-}] / [\text{H}_3\text{AsO}_3^0] = 10\)

3) Microbial metabolism:
   a. Calculate the \( \Delta G^0 \) for sulfate reduction...
      \[ \text{SO}_4^{2-} + 9\text{H}^+ + 8e^- = \text{HS}^- + 4\text{H}_2\text{O} \]
      ...linked to acetate oxidation:
      \[ \text{CH}_3\text{COO}^- + 2\text{H}_2\text{O} = 2\text{CO}_2 + 7\text{H}^+ + 8e^- \]
   b. Calculate the \( \Delta G \) for the reaction in a system at \( \text{pH}=6.5 \) with the following activities: \([\text{SO}_4^{2-}] = 10^{-3}; [\text{HS}^-] = 10^{-6}; [\text{CH}_3\text{COO}] = 10^{-6}; [\text{CO}_2] = 10^{-6}\)
   c. Calculate the \( \Delta G \) for the reaction in a system at \( \text{pH}=6.5 \) where the reactants are almost all consumed and the products have built up to higher activities: \([\text{SO}_4^{2-}] = 10^{-6}; [\text{HS}^-] = 10^{-3}; [\text{CH}_3\text{COO}] = 10^{-7}; [\text{CO}_2] = 10^{-5}\)
   d. Which species is the electron donor?
   e. Which is the electron acceptor?
   f. Comment on the ability of microbial respiration to continue as the microbes use up the electron acceptor and donor, and the metabolic products build up.
   g. Does it matter if you choose the \( \Delta G \) approach or the \( E \) approach to do this type of calculation (parts a through c)? Give a simple reason why the two approaches are equivalent. Also give one reason why \( \text{Eh} \) might be more useful in the field.

4) Exchange and sorption reactions:
   a. Write a chemical reaction for exchange of \( \text{Ca}^{2+} \) for \( \text{Na}^+ \) on the surface of a clay mineral. Write it so \( \text{Na}_2\text{X} \) is on the product side.
   b. Write a mass action expression for this reaction.
   c. Imagine a clay particle bathed in a solution with dissolved \( \text{Na}^+ \) and \( \text{Ca}^{2+} \) (ignore other cations for this problem). Calculate the ratio of sorption sites occupied by \( \text{Ca}^{2+} \) to those occupied by \( \text{Na}^+ \) for the following conditions:
      \[ K_{\text{Na-Ca}} = 1.6; [\text{Na}^+] = 0.47; [\text{Ca}^{2+}] = 0.01 \]
   d. Now calculate the ratio of sorption sites occupied by \( \text{Ca}^{2+} \) to those occupied by \( \text{Na}^+ \) for a much more dilute solution with the same Na/Ca ratio:
      \[ K_{\text{Na-Ca}} = 1.6; [\text{Na}^+] = 0.0047; [\text{Ca}^{2+}] = 0.0001 \]
   e. Qualitatively, what exchange of ions tends to occur when a marine sedimentary rock containing exchangeable clay minerals first comes into contact with dilute groundwater. The dilute groundwater has roughly the same Na/Ca ratio as seawater.